Υ Production in Ultra-Peripheral Heavy Ion Collisions

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Exclusive Υ production, $A+A \rightarrow A+A+\Upsilon$ in ultra-peripheral heavy ion collisions is sensitive to shadowing in the nuclear targets. Υ production occurs when a photon from the electromagnetic field of one nucleus fluctuates to a $b\overline{b}$ dipole, which then interacts with the other nucleus and emerges as an Υ.

We calculate the cross section for $\Upsilon(1S)$ production in silicon-silicon collisions at a center of mass energy of 250 GeV per nucleon, as can be produced at RHIC, and for lead-lead collisions at a center of mass energy of 5.5 TeV/nucleon, as will occur at the LHC. The calculation uses $\gamma p \rightarrow l^+l^- p$ data from HERA; the lepton pairs are an unknwon mixture of $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$; theoretical considerations indicate the mixture is largely $\Upsilon(1S)$. The cross section is[1]

$$\sigma = \int dk \frac{dN_\gamma}{dk} \sigma_\Upsilon(k)$$

where dN/dk is the photon flux, obtained using the Weizsacker-Williams method. The upsilon cross section $\sigma_\Upsilon(k)$ is taken from HERA data[2]: $\sigma(\gamma p \rightarrow \Upsilon p) = 0.06 W^{1.7}$pb, where W is the γp center of mass energy. The $b\overline{b}$ system is small, so the cross section for coherent photoproduction on a nuclear target scales as A^2.

The HERA measurements didn't differentiate between different Υ states, so our results also do not. The photon energy k is related to the Υ rapidity via $y = 1/2\ln(2k/M_\Upsilon)$ where M_Υ is the Υ mass.

Figure 1a shows $d\sigma/dy$ for Si-Si collisions at RHIC. Silicon is is smaller than gold, with a higher photon energy cutoff, and can be collided at a higher per-nucleon energy and luminosity. At the design luminosity of 4.4×10^{28} cm^{-2} s^{-1}, the production rate for $|y| < 1$ is 220 in 10^7 sec. After the branching ratio (5% total to $e^+e^- + \mu^+\mu^-$), this is barely detectable. However, the proposed RHIC II upgrade would increase the luminosity by a factor of 40; this would lead to an observable signal.

Figure 1b shows $d\sigma/dy$ for Pb-Pb collisions at the LHC. At the LHC Pb-Pb design luminosity of 10^{26} cm^{-2} s^{-1}, the production rate for $|y| < 1$ is 1 in 2 minutes. With a large acceptance detector, a good measurement is obtainable even in a 1 month run.

These calculations do not include shadowing. At mid-rapidity, the production is sensitive to gluons with $x = 0.04$ at RHIC, and $x = 0.0017$ at the LHC. Gluon shadowing could significantly reduce the cross section[3].

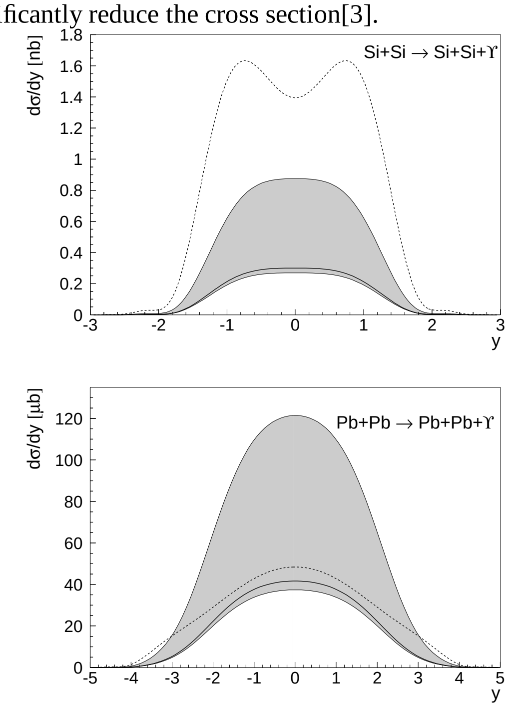

FIG. 1: $d\sigma/dy$ for (a) $Si+Si \rightarrow Si+Si+\Upsilon$ at RHIC and (b) $Pb+Pb \rightarrow Pb+Pb+\Upsilon$ at the LHC. The solid curves are for $\sigma \approx W^{1.7}$, while the dashed curves assume $W^{0.8}$ scaling, as is observed for J/ψ photoproduction. The shaded bands show the uncertainties in the HERA measurement.

REFERENCES

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[1] S. Klein and J. Nystrand, Phys. Rev. **C60**, 014903 (1999).
[2] J. Breitweg *et al.*, Phys. Lett. **B437**, 432 (1998).
[3] L. Frankfurt, M. Strikman and M. Zhalov, Phys. Lett. **B540**, 220 (2002).